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(54) **Semitransparent electrophoretic information displays (EPID) employing mesh like electrodes.**

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US-A- 4 071 430
US-A- 4 655 897
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(73) Proprietor : **COPYTELE INC.**
900 Walt Whitman Road
Huntington Station New York 11746 (US)

(72) Inventor : **Disanto, Frank J.**
47 Windsor Gate Drive
North Hills, New York 11040 (US)
Inventor : **Krusos, Denis A.**
Middlehollow Road
Lloyd Harbor, New York 11743 (US)

(74) Representative : **Wombwell, Francis et al**
Potts, Kerr & Co.
15, Hamilton Square
Birkenhead Merseyside L41 6BR (GB)

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Description

Background of the Invention

This invention relates to electrophoretic information displays (EPID) in general and more particularly to an EPID display employing a mesh like electrode.

The prior art is replete with a number of various patents and articles concerning electrophoretic displays. Such electrophoretic displays have been widely described and disclosed in the prior art, and essentially the assignee herein, namely--Copytele, Inc. of Huntington Station, New York, has recently developed an electrophoretic display which has an image area of approximately 28 x 21.6 cm (11 x 8 1/2 inches) and is designed to be used either as a separate display or to be combined with other displays. The company has the ability to combine as many as four such displays to create image areas as large as approximately 56 x 43.2 cm (22 x 17 inches).

The information on such displays can be changed either locally or remotely and can be viewed at an angle of nearly 180°. Such displays have extremely high resolution and can accommodate over 160,000 pixels within an image area of approximately 7.1 cm (2.8 inches) diagonally. In regard to such displays, reference is made to U.S. 4,655,897 issued on April 7, 1987 entitled ELECTROPHORETIC DISPLAY PANELS AND ASSOCIATED METHODS to Frank J. DiSanto and Denis A. Krusos and assigned to Copytele, Inc., the assignee herein.

In that patent there is described an electrophoretic display panel which includes a planar transparent member having disposed on a surface a plurality of vertical conductive lines to form a grid of lines in the Y direction. On top of the grid of vertical lines there is disposed a plurality of horizontal lines which are positioned above the vertical lines and insulated therefrom by a thin insulating layer at each of the intersection points. Spaced above the horizontal and vertical line pattern is a conductive plate. The space between the conductive plate and the X and Y line pattern is filled with an electrophoretic dispersion containing chargeable pigment particles.

When a voltage is impressed on the X and Y lines, pigment particles which are located in wells or depressions between the X and Y pattern are caused to migrate towards the conductive plate and are deposited on the plate in accordance with the bias supplied to the X and Y conductors.

There is described in that patent an electrophoretic dispersion suitable for operation with the display as well as techniques for fabricating the display. Hence, in this manner the displays can be fabricated to contain large effective display surfaces while being relatively thin and which are capable of high resolution and relatively low power. As indicated, the above-noted patent and others include information concerning the fabrication, operation and resolution of such displays.

See also U.S. Patent 4,772,820 entitled "Monolithic Flat Panel Display Apparatus" issued on September 20, 1988 to Frank J. DiSanto et al. and assigned to the assignee herein. This patent shows an electrophoretic display as well as methods for fabrication and operating such a display.

See also U.S. Patent 4,742,345 entitled "Electrophoretic Display Panel Apparatus And Methods Therefor" by Frank J. DiSanto et al. and assigned to the assignee herein. This patent shows such a display having improved alignment and contrast characteristics and structure and methods for aligning and operating such a display.

See also U.S. Patent 4,746,917 entitled "Methods And Apparatus For Operating An Electrophoretic Display Between A Display And A Non-Display Mode" issued on May 24, 1988 to Frank J. DiSanto et al. and assigned to the assignee herein. This patent shows and describes a power supply circuit for operating such a display between a display and a non-display mode.

As one can ascertain from the prior art, the electrophoretic display has been thoroughly investigated and essentially it is a continuing object to provide more reliable operation as well as to provide displays which permit greater control of the image producing pigment particles as propagating within the display.

The electrophoretic effect is associated with working fluids which includes a dispersion of electrophoretic particles. These particles may be fabricated from an opaque dielectric material or a pigment which particles are suspended in a colored non-conducting suspension medium. The particles preferably are uniformly distributed throughout the suspension medium and the contrast between the particles and the suspension medium is the mechanism which enables one to formulate an image.

When the composite material is subjected to an electric field, the particles are caused to move electrophoretically in the direction of either the cathode or the anode. These particles are deposited upon the respective structure to cause that structure to assume the color of the particle which, for example, may be grey, white or some other color depending upon the pigment utilized. Hence, as one can ascertain, by selectively moving the particles one can produce images based on the migration and orientation of the particles with respect to a charged surface. As indicated, this effect is well known as for example ascertained by the above-noted prior art and many of the references cited against such prior art.

As one will immediately understand, it is a major object in all such displays to produce a reliable display as well as to provide a uniform and rapid movement of the particles. In prior art displays, extreme difficulty was experienced when attempting to move the par-

ticles at high speeds and to further control the particles so that a uniform image is displayed.

It is an object of the present invention to provide a mesh electrode which mesh electrode provides greater control of the pigment particles and therefore provides a display which is more reliable and easier controlled than those of the prior art.

Summary of the Invention

In an electrophoretic display of the type having an XY matrix assembly consisting of a grid of vertical lines intersected by a grid of horizontal lines and insulated therefrom, with an anode electrode spaced from said matrix assembly and with an electrophoretic dispersion located between said anode and matrix assembly, the improvement therewith of a mesh like electrode structure located between said matrix assembly and said anode electrode as defined in claims 1 and 9.

Brief Description of the Figures

FIG. 1 is a partial plan view of an electrophoretic display apparatus according to this invention; and

FIG. 2 is a plan view of an electrophoretic display showing certain aspects of the present invention.

Detailed Description of the Figures

Referring to Fig. 1, there is shown a side view of a typical electrophoretic display 10.

The display 10 of Fig. 1 is filled with an electrophoretic solution or dispersion 20 which includes light colored pigment particles suspended in a dark dye solution. For examples of such solutions and techniques, reference is made to the above-cited U.S. Pat. No. 4,655,897.

As seen from Fig. 1, the display contains a front glass sheet or viewing surface 21. The eye of viewer 15 is shown viewing the front of the display via the glass sheet 21. Disposed upon the glass sheet 21 by suitable etching techniques are columns 23 and rows 25. The rows are made from an extremely thin layer of indium-tin-oxide (ITO) while the columns are made from thin layers of aluminum. These patterns are provided in extremely thin layers and essentially constitute an X Y matrix. The layers of ITO are relatively thin, being approximately 300 Angstroms in thickness. In any event, the grid or columns and the rows or cathodes are spaced from one another and insulated from one another by means of an insulating layer 22.

While the grids and cathodes have been specified in terms of rows and columns, it is immediately apparent that the terms can be interchanged as desired. In any event, each of the grid and cathode intersections are associated with a pigment well 24. These wells contain the electrophoretic solution which is in the cavity 20. The columns and rows are separated from a back electrode 26 or anode plate which is also fabricated on a sheet of glass 27 and constitutes a thin layer of ITO. The anode electrode is essentially an extremely thin planar layer of ITO deposited upon a sheet of glass, as can be seen in many of the above-cited references. The spacers such as 32 and 33 can be implemented in many different ways and essentially serve to mechanically separate the display cell or panel 10.

Shown positioned between the grid cathode structure and the anode 26 is a mesh electrode 30. The mesh electrode 30 is fabricated from a thin sheet of stainless steel having a plurality of apertures therein to create a mesh or screen like structure. The electrodes of the display are biased by means of the power supply 50. The supply 50 operates similar to that shown in the above cited patent U.S. 4,746,917. As indicated, the anode electrode 26 is a thin layer of ITO which is semi-transparent and highly reflective. The electrode 30 contains a plurality of apertures and due to the mesh like construction will allow light to pass via the apertures. The configuration described employs the anode 26 with the mesh like electrode 30. This configuration permits greater control of the pigment particles due to the various ratios of the potential applied to the electrode 30 as compared to that applied to the anode 26.

An extremely important aspect of the electrophoretic display which will enhance operation even further, is the possibility of back lighting the display. As seen in FIG. 1, there is shown a bulb 40 which appears at the back of the display while the viewer's eye 15 is at the front of the display. If the bulb is illuminated then the pattern, which is disposed upon the cathode surface, will stand out due to the fact that the light source 40 will tend to increase the contrast of the display. The electrophoretic solution can be illuminated by means of the light source as 40 thus creating greater contrast and enabling the display to be even clearer.

The configuration, as shown in FIG. 1, may be simply constructed using methods as taught by many of the references cited above. For example, a layer of insulating material is first coated on top of the ITO layer 26 which ITO layer is deposited upon the glass substrate 27. A layer of metal is then coated on the insulating material. This metal layer is patterned by a photolithographic technique to produce a mesh pattern. The insulating material is then plasma etched to produce the wells or apertures which therefore communicate between the mesh and the anode with the mesh being insulated from the anode by means of an insulating layer 41 as shown in FIG. 1.

In order to operate the display of FIG. 1, normal grid and cathode voltages are employed, as indicated

and shown in the above references. The voltage employed on the mesh electrode or the mesh anode is a relatively high voltage designated as for example +HV and this voltage is applied during the hold and write modes of the display. The electrode 26 designated as the anode, is connected to a voltage which is +HV -ΔV. The voltage ΔV is selected to be between 5 and 10% less than the voltage +HV. Thus the mesh 30 is positive relative to the anode 26 and hence the pigment particles stop at the mesh permitting a maximum amount of illumination from the back lighting source 40. It is of course understood that if the anode 26 is completely eliminated, the mesh electrode 30 can be deposited directly on the glass sheet 27 by the above-described methods as should be obvious to those skilled in the art. In this manner a maximum amount of light will pass through the apertures created in the mesh.

In operation of the display the pigment particles contained in the electrophoretic solution 20 are brought forward towards the viewing surface in order to fill the wells formed between the rows and columns. Once a well such as well 24 is filled, the voltage on the rows, columns, and anode is then set such that the wells remain filled but pigment spaced between the rear cover and the columns are swept unto the mesh (30) and anode (26). The viewing side 21 is the color of the pigment in the wells.

By selectively applying voltages to the rows and columns, the pigment in individual wells 24 (at the intersection of the rows and columns selected) is forced out of the wells exposing the dye solution and making that intersection (pixel) dark. The removal of the pigment from the wells is not instantaneous but requires a period of time which depends upon the dimension of the cell or display, the fluid components, and the various applied voltages. The use of the mesh electrode 30 operates to more rapidly propel the pigment particles due to the increased field provided by the additional mesh electrode and hence affords a more rapid removal of particles from the wells. This is also due to the mesh like construction as the apertures in the mesh electrode enhance the field strength.

Referring to Fig. 2, there is shown a planar plan view of an enlarged representation of an electrophoretic display cell or panel according to Fig. 1.

As seen in Fig. 2, each well 24 is accommodated between an intersection of a column 23 which is insulatively separated from a row layer of ITO 25. The well 24 forms a pixel area which is indicative of an X Y intersection on the ITO display.

The pigment particles of course travel between the cathode and anode. As shown in FIG. 2, the anode may be the mesh-like structure 30 or may constitute a separate mesh structure fabricated directly on the layer of glass as above described or a stainless steel mesh 30 may be interposed between the anode and a cathode grid structure as indicated. As seen in FIG. 2. the mesh contains a plurality of apertures which are for example circular holes. It is immediately understood that the mesh may contain any shaped apertures, such as rectangular, square, triangular and so on. Essentially the apertures are extremely small. The mesh is a hardened stainless steel mesh available from many sources. Each aperture is between 0.254mm to 0.76mm (10 to 30 mils) in diameter with the space between apertures being of the same magnitude, namely 0.254mm to 0.76mm (10 to 30 mils). Preferably the apertures are approximately 0.38mm (15 mils) in diameter with the space between the apertures about 0.38mm to 0.51mm (15 to 20 mils). Hence, as one can ascertain, due to the extremely large number of apertures and due to the spacing between apertures, the hardened stainless steel sheet appears as a total mesh-like structure which is integrally formed and highly conductive. Hence the same can act as an anode electrode or as an intermediate electrode to aid and assist in controlling the pigment particles.

The above-noted mesh structure creates an electrophoretic display having superior operating characteristics over those provided in the prior art.

Claims

1. An electrophoretic display (10) of the type having an XY matrix assembly consisting of a grid of vertically oriented, electrically conductive lines (23) intersected by a grid of horizontally oriented, electrically conductive lines (25) and insulated therefrom, with a semi-transparent anode electrode (26) spaced from said matrix assembly, with an electrophoretic dispersion (20) located between said anode and matrix assembly, and with a voltage source (50) for biasing the matrix assembly and anode electrode, characterised by a mesh like electrode structure (30) located between said matrix assembly and said anode electrode and connected to said voltage source, said voltage source being adapted to always bias said mesh electrode at a greater positive potential than said anode electrode and said matrix assembly.

2. The electrophoretic display according to Claim 1 wherein said anode electrode (26) comprises a thin layer of ITO with said mesh like electrode (30) located between said anode electrode and said matrix and operative when biased to further control electrophoretic particles.

3. The electrophoretic display according to Claim 2 wherein said mesh like electrode (30) is a planar sheet of a conductive material having a plurality of apertures on the surface to form a mesh like

structure.

4. The electrophoretic display according to Claim 3 wherein said conductive material is stainless steel.

5. The electrophoretic display according to Claim 4 wherein said apertures are circular in shape, each having a diameter of between 0.254 - 0.76 mm (10-30 mils) and spaced one from the other between 0.254 - 0.76 mm (10-30 mils).

6. The electrophoretic display according to Claim 1 wherein said anode electrode (26) is deposited on a planar glass member (27).

7. The electrophoretic display according to Claim 1 further including means for applying a higher positive potential to said mesh electrode (30) than said anode electrode (26) to cause pigment particles to migrate to and stop at said mesh electrode.

8. The electrophoretic display according to claim 6 further characterised by a light source (40) located in proximity to said anode electrode to cause light to pass through said anode structure to said matrix structure for illuminating said display.

9. A method of operating an electrophoretic display (10) having a mesh electrode (30) between an anode electrode (26) on a back surface (27) and an XY matrix assembly consisting of a grid of vertically oriented, electrically conductive lines (23) intersected by a grid of horizontally oriented, electrically conductive lines (25) and insulated therefrom, said matrix assembly, said anode electrode and said mesh electrode being connected to a voltage source (50), and said XY matrix defining a pigment well (24) adjacent a viewing surface (21) at each intersection of conductive lines, characterized by the steps of:

applying a potential bias to said anode electrode; and

applying to said mesh electrode a bias of a more positive potential than that applied to said anode electrode and said matrix assembly, to cause pigment particles to propagate to and stop at said mesh electrode.

10. The method according to Claim 9, further characterized by the step of applying a bias, before said anode and mesh bias applying steps, to said XY matrix until selected pigment wells are filled, wherein the selected wells remain filled but pigment spaced between the rear cover and columns are swept on the mesh electrode and anode electrode when the biases are applied to said anode electrode and said mesh electrode.

11. The method according to claim 10 further chacterized by the step of selectively applying voltages to said electrically conductive lines to force pigment from a plurality of said selected wells during said anode electrode and mesh electrode bias applying steps, wherein said mesh electrode operates to more rapidly propel the pigment particles from said plurality of selected wells.

Patentansprüche

1. Elektrophoretische Anzeigevorrichtung (10) des Typs mit einer XY-Matrixanordnung, die aus einem Gitter aus vertikal orientierten, elektrisch leitenden Leitungen (23) besteht, die von einem Gitter aus horizontal orientierten, elektrisch leitenden Leitungen (25) geschnitten werden und dagegen isoliert sind, mit einer von der Matrixanordnung beabstandeten, halbtransparenten Anodenelektrode (26), mit einer elektrophoretischen Dispersion (20), die sich zwischen der Anode und der Matrixanordnung befindet, sowie mit einer Spannungsquelle (50) zum Vorspannen der Matrixanordnung und der Anodenelektrode, gekennzeichnet durch eine netzartige Elektrodenstruktur (30), die sich zwischen der Matrixanordnung und der Anodenelektrode befindet und mit der Spannungsquelle verbunden ist, wobei die Spannungsquelle dazu geeignet ist, die Netzelektrode stets auf einem größeren positiven Potential als die Anodenelektrode und die Matrixanordnung vorzuspannen.

2. Elektrophoretische Anzeigevorrichtung nach Anspruch 1, bei welcher die Anodenelektrode (26) eine dünne Schicht aus ITO aufweist, wobei sich die netzartige Elektrode (30) zwischen der Anodenelektrode und der Matrix befindet und bei Vorspannung wirksam ist, um elektrophoretische Teilchen weiter zu steuern.

3. Elektrophoretische Anzeigevorrichtung nach Anspruch 2, bei welcher die netzartige Elektrode (30) eine planare Tafel aus einem leitenden Material mit einer Vielzahl von Öffnungen an der Oberfläche zur Bildung einer netzartigen Struktur ist.

4. Elektrophoretische Anzeigevorrichtung nach Anspruch 3, bei welcher das leitende Material Edelstahl ist.

5. Elektrophoretische Anzeigevorrichtung nach Anspruch 4, bei welcher die Öffnungen kreisförmig sind, wobei jede einen Durchmesser zwischen

0,254 - 0,76 mm aufweist, und zwischen 0,254 - 76 mm voneinander beabstandet sind.

6. Elektrophoretische Anzeigevorrichtung nach Anspruch 1, bei welcher die Anodenelektrode (26) auf einem planaren Glaselement (27) aufgebracht ist.

7. Elektrophoretische Anzeigevorrichtung nach Anspruch 1, die ferner Mittel zum Anlegen eines höheren positiven Potentials an die Netzelektrode (30) als an die Anodenelektrode (26) aufweist, um Pigmentteilchen zu veranlassen, zu der Netzelektrode zu wandern und dort anzuhalten.

8. Elektophoretische Anzeigevorrichtung nach Anspruch 6, ferner gekennzeichnet durch eine Lichtquelle (40), die sich in der Nähe der Anodenelektrode befindet, um den Durchgang von Licht durch die Anodenstruktur zu der Matrixstruktur zur Beleuchtung der Anzeigevorrichtung zu veranlassen.

9. Verfahren zum Betrieb einer elektrophoretischen Anzeigevorrichtung (10) mit einer Netzelektrode (30) zwischen einer Anodenelektrode (26) an einer Rücktfläche (27) und einer XY-Matrix-Einheit, die aus einem Gitter aus vertikal orientierten, elektrisch leitenden Leitungen (23) besteht, die von einem Gitter aus horizontal orientierten, elektrisch leitenden Leitungen (25) besteht, die dagegen isoliert sind, wobei die Matrixanordnung, die Anodenelektrode und die Netzelektrode mit einer Spannungsquelle (50) verbunden sind und die XY-Matrix an jedem Schnittpunkt von leitenden Leitungen eine Pigmentwanne (24) angrenzend an eine Beobachtungsfläche (21) bildet, gekennzeichnet durch die folgenden Schritte:

Anlegen einer Potentialvorspannung an die Anodenelektrode; und

Anlegen einer Vorspannung mit einem positiveren Potential als dem an die Anodenelektrode und die Matrixanordnung angelegten an die Netzelektrode, um Pigmentteilchen zu veranlassen, sich zu der Netzelektrode fortzupflanzen und dort anzuhalten.

10. Verfahren nach Anspruch 9, ferner gekennzeichnet durch den Schritt des Anlegens einer Vorspannung an die XY-Matrix vor den Schritten des Anlegens der Anoden- und Netzvorspannung, bis ausgewählte Pigmentwannen gefüllt sind, wobei die ausgewählten Wannen gefüllt bleiben, aber zwischen der Rückabdeckung und den Spalten beabstandete Pigmente an die Netzelektrode und die Anodenelektrode geschwemmt werden, wenn die Vorspannungen an die Anodenelektrode und die Netzelektrode angelegt werden.

11. Verfahren nach Anspruch 10, ferner gekennzeichnet durch den Schritt des selektiven Anlegens von Spannungen an die elektrisch leitenden Leitungen, um während der Schritte des Anlegens einer Anodenelektroden- und Netzelektrodenvorspannung Pigmente aus einer Vielzahl von ausgewählten Wannen zu drängen, wobei die Netzelektrode so arbeitet, um die Pigmentteilchen schneller aus der Vielzahl von ausgewählten Wannen zu treiben.

Revendications

1. Afficheur électrophorétique (10) du type pourvu d'un assemblage en matrice X Y consistant en une grille de lignes électriquement conductrices (23) orientée verticalement, coupée par une grille de lignes électriquement conductrices (25) orientée horizontalement et isolée par rapport à celle-ci, avec une électrode d'anode semi-transparente (26) espacée par rapport audit assemblage en matrice, avec une solution électrophorétique (20) située entre lesdites anode et assemblage en matrice, et avec une source de tension (50) destinée à polariser l'assemblage en matrice et l'électrode d'anode, caractérisé par une structure d'électrode en forme de treillis (30) située entre ledit assemblage en matrice et ladite électrode d'anode et reliée à ladite source de tension, ladite source de tension étant adaptée de façon à polariser en permanence ladite électrode en treillis à un potentiel positif supérieur à celui de ladite électrode d'anode et dudit assemblage en matrice.

2. Afficheur électrophorétique selon la revendication 1, dans lequel ladite électrode d'anode (26) comprend une fine couche d'ITO, ladite électrode en forme de treillis (30) étant située entre ladite électrode d'anode et ladite matrice et agissant, lorsqu'elle est polarisée, de façon à aussi commander les particules électrophorétiques.

3. Afficheur électrophorétique selon la revendication 2, dans lequel ladite électrode en forme de treillis (30) est une feuille plane d'un matériau conducteur disposant d'une pluralité d'ouvertures sur la surface de façon à former une structure en forme de treillis.

4. Afficheur électrophorétique selon la revendication 3, dans lequel ledit matériau conducteur est de l'acier inoxydable.

5. Afficheur électrophorétique selon la revendication 4, dans lequel lesdites ouvertures sont de

forme circulaire, chacune ayant un diamètre situé entre 0,254 et 0,76 mm (10 à 30 mils) et sont espacées l'une de l'autre de 0,254 à 0,76 mm (10 à 30 mils) environ.

6. Afficheur électrophorétique selon la revendication 1, dans lequel ladite électrode d'anode (26) est déposée sur un élément en verre plan (27).

7. Afficheur électrophorétique selon la revendication 1, comprenant en outre un moyen pour appliquer un potentiel positif plus élevé sur ladite électrode en treillis (30) que celui de ladite électrode d'anode (26) de façon à provoquer la migration des particules de pigment vers ladite électrode en treillis et leur arrêt sur celle-ci.

8. Afficheur électrophorétique selon la revendication 6, caractérisé en outre par une source de lumière (40) située à proximité de ladite électrode d'anode de façon à faire passer la lumière à travers ladite structure d'anode vers ladite structure en matrice afin d'éclairer ledit afficheur.

9. Procédé de commande d'un afficheur électrophorétique (10) pourvu d'une électrode en treillis (30) disposée entre une électrode d'anode (26) sur une face arrière (27) et un assemblage en matrice X Y consistant en une grille de lignes électriquement conductrices (23) orientée verticalement, coupée par une grille constituée de lignes électriquement conductrices (25) orientée horizontalement et isolée par rapport à celle-ci, ledit assemblage en matrice, ladite électrode d'anode et ladite électrode en treillis étant reliés à une source de tension (50), et ladite matrice X Y définissant un puits de pigment (24) adjacent à une surface de visualisation (21) à chaque intersection des lignes conductrices, caractérisé par les étapes de :

application d'une tension de polarisation sur ladite électrode d'anode ; et

application sur ladite électrode en treillis d'une polarisation avec une tension positive supérieure à celle appliquée sur ladite électrode d'anode et sur ledit assemblage en matrice, de façon à provoquer la propagation des particules de pigment vers ladite électrode en treillis et leur arrêt sur celle-ci.

10. Procédé selon la revendication 9, caractérisé en outre par l'étape d'application d'une polarisation, avant lesdites étapes d'application d'une polarisation sur l'anode et le treillis, sur ladite matrice X Y jusqu'à ce que les puits de pigment sélectionnés soient remplis, dans lequel les puits sélectionnés restent remplis mais les pigments isolés entre le couvercle arrière et les colonnes sont balayés sur l'électrode en treillis et l'électrode d'anode lorsque les polarisations sont appliquées sur ladite électrode d'anode et sur ladite électrode en treillis.

11. Procédé selon la revendication 10, caractérisé en outre par les étapes d'application de façon sélective de tensions sur lesdites lignes électriquement conductrices de façon à forcer les pigments issus d'une pluralité desdits puits sélectionnés pendant lesdites étapes d'application d'une polarisation sur les électrode d'anode et électrode en treillis, dans lequel ladite électrode en treillis agit de façon à propulser plus rapidement les particules de pigment issues de ladite pluralité de puits sélectionnée.

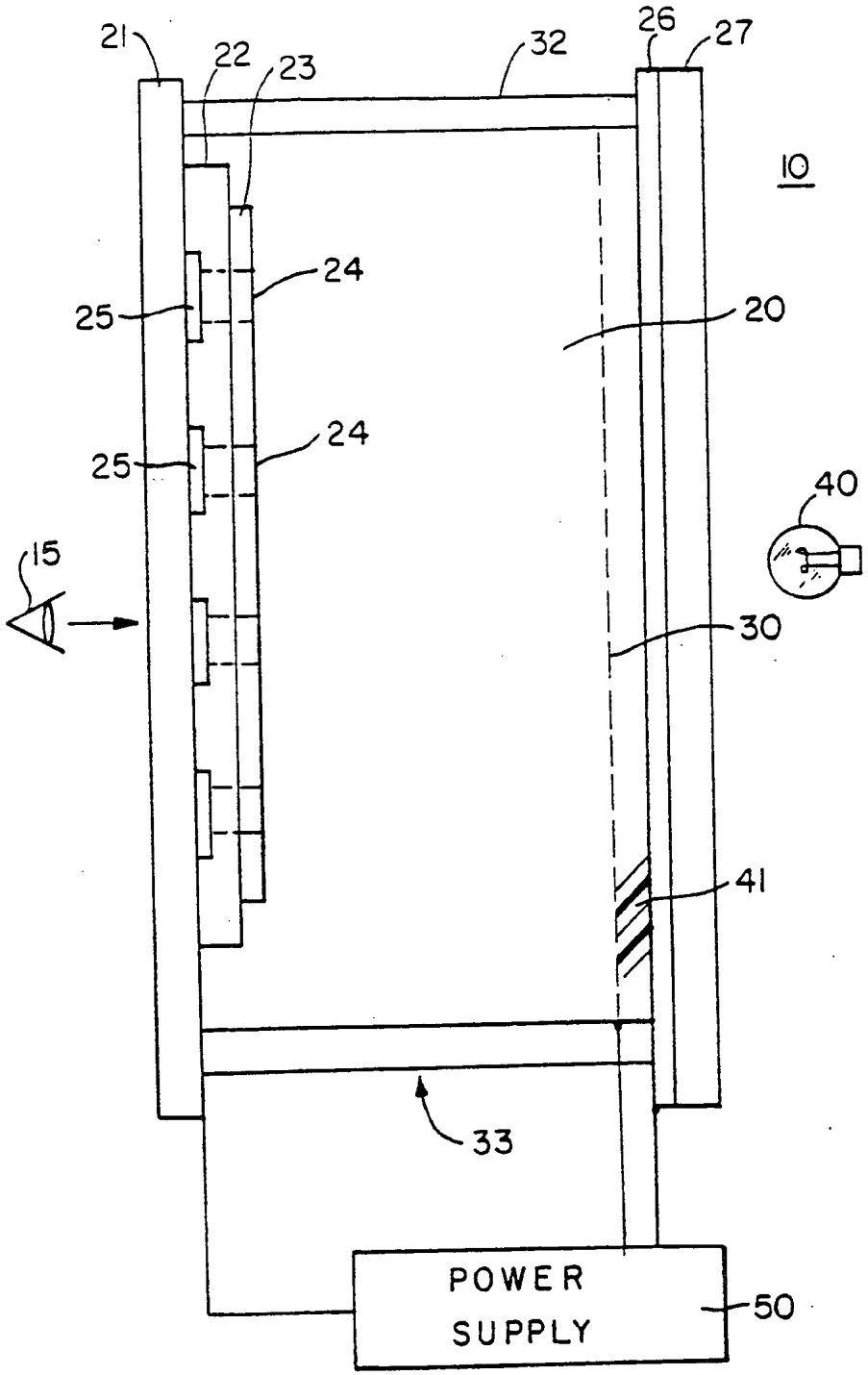

FIG. 1

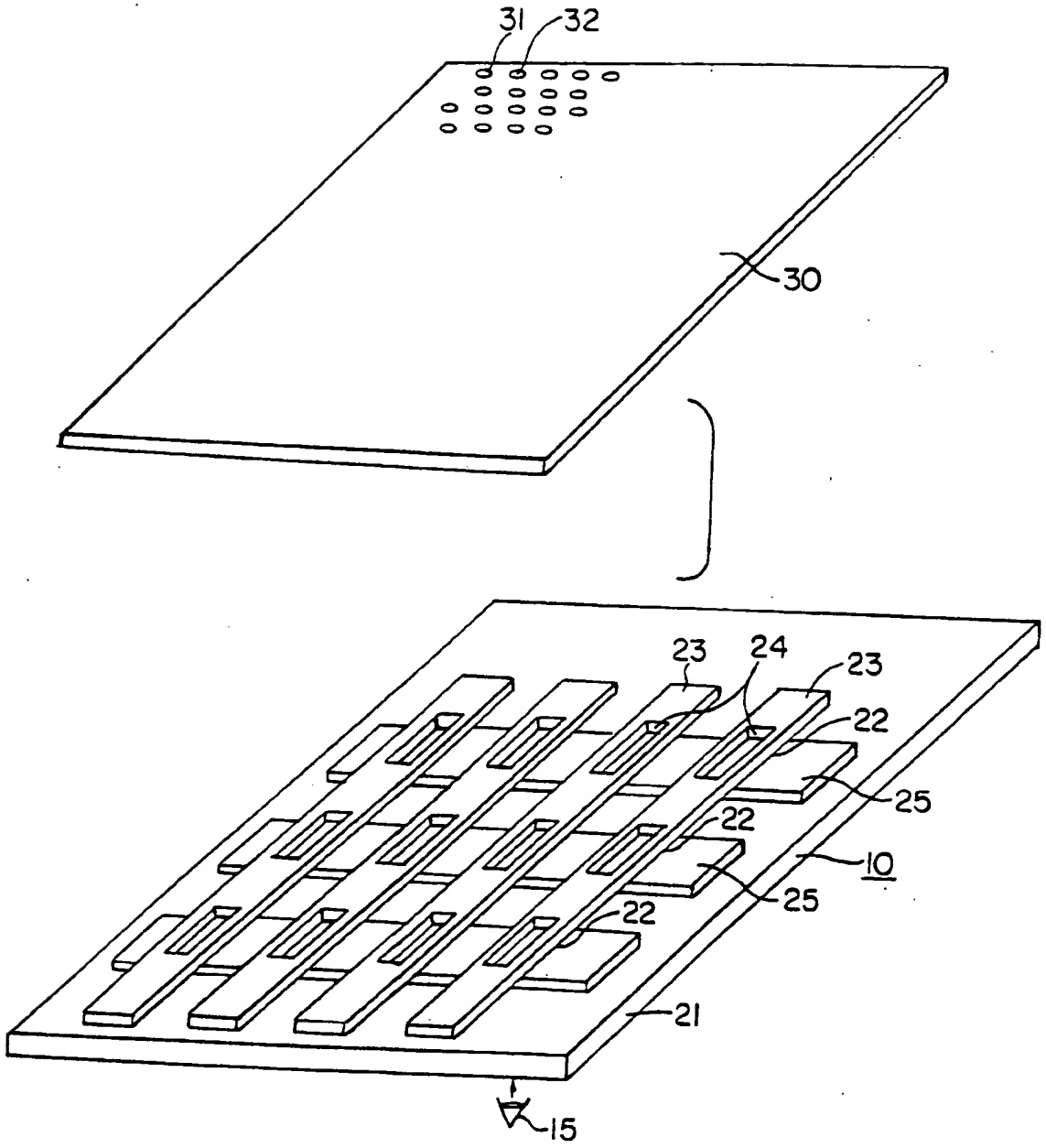

FIG. 2